What is HexSim?

- **It is a computer simulation model.**
- **It is useful for evaluating wildlife population responses to human activities.**
- **It is modern and sophisticated, but flexible and easy to use.**
- **It can be used with a large range of places, problems, and questions.**

How is HexSim Different?

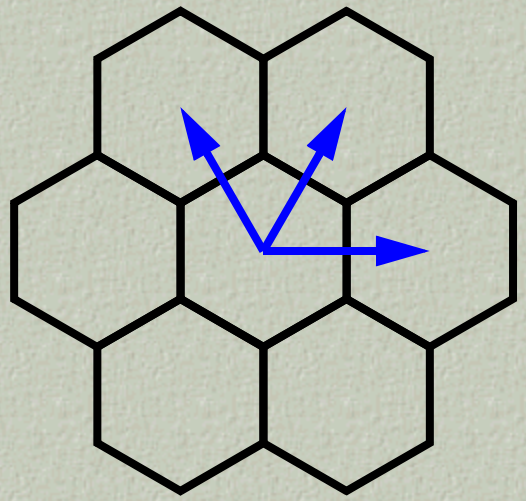
- **It has a wide range of potential applications.**
- **It contains no simplifying assumptions about the biology or ecology of the study systems**
- **Every individual can have unique properties that change throughout their lifetimes**
- **Can simulate population interactions, stressor interactions, landscape genetics, and more**
- **Modern and easy to use, with graphical user interfaces (GUI) for every model component**

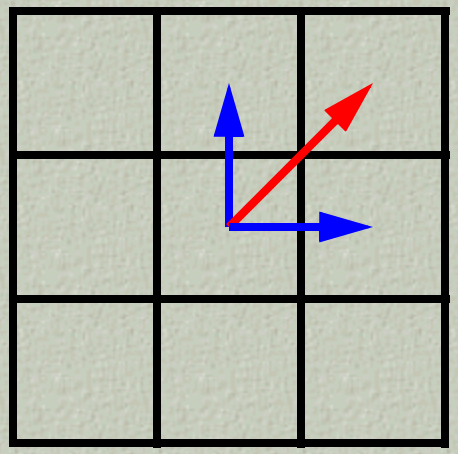
HexSim Features

- Spatially-Explicit and Individual-Based
- Dynamic Landscape Change
- General and Flexible
- Multi-Stressor with Interactions
- Multi-Population with Interactions
- Females-only or 2-Sex Simulations
- Two Mate-Finding Sub-Models
- Life History Events Stratified by Traits
- Modern Interface
- Useful Outputs

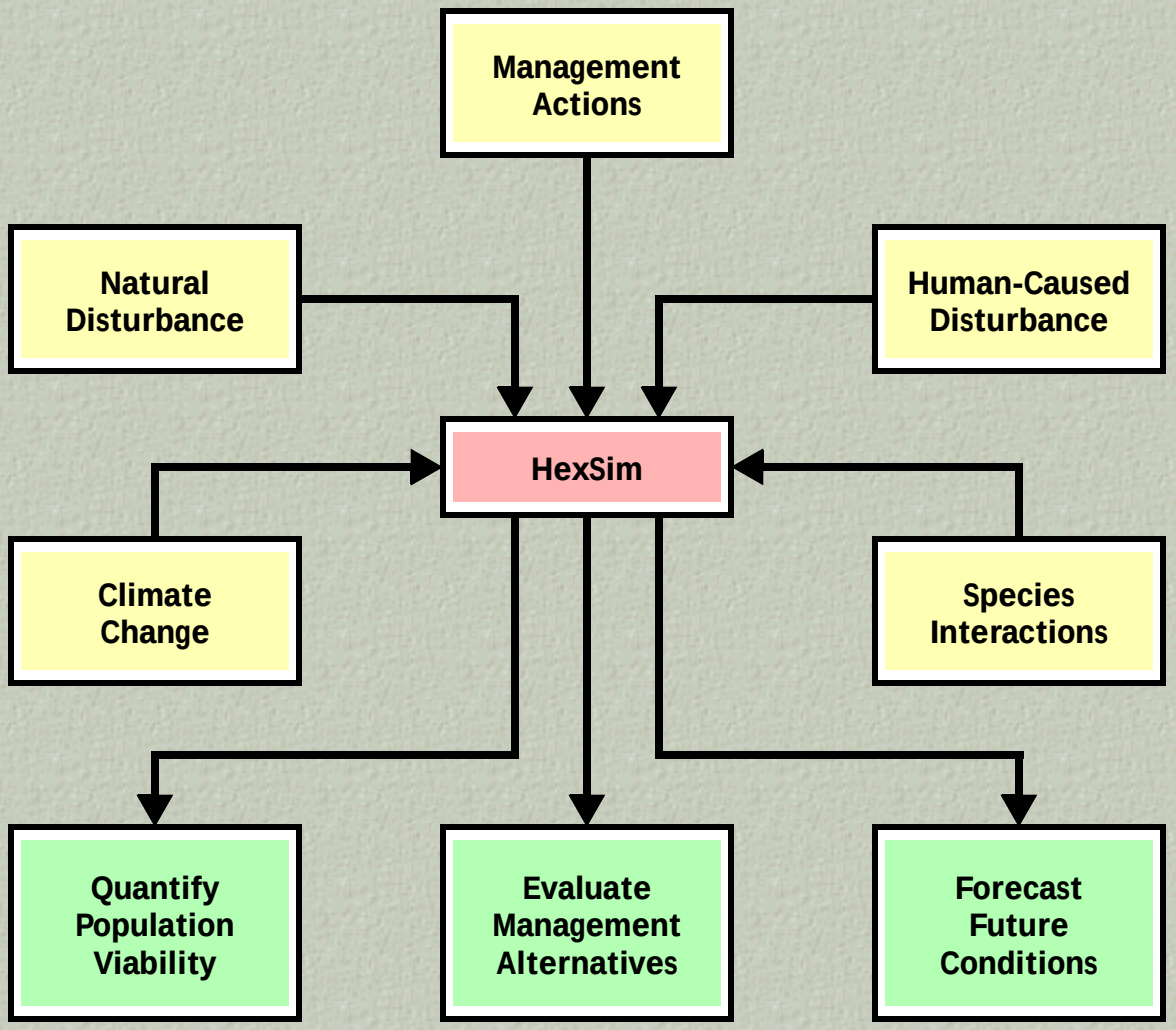
Why Hexagons?

- They provide a space-filling tesselation
- Each of a hexagon's neighbors is the same distance away.





What Can HexSim Do?



Example HexSim Analyses

- **Wildlife Response Modeling.** **Drivers include landscape structure, disturbance regimes, etc...**
- **Alternative Futures Analysis.** **How will various life histories respond to anticipated changes...**
- **Quality Assurance.** **What minimum amount of model complexity is necessary for accuracy...**
- **Wildlife-Related Concerns.** **What about diseases, connectivity, resilience, invasive species, etc...**

Model Inputs

- **Spatial Data.** Can be real or fabricated, one or multiple layers, static or time series...
- **Life History Data.** Can be real or fabricated or a hybrid. Data limits model complexity...
- **Disturbance Regimes.** Spatial, temporal, simple, complex, local, regional, etc...
- **Stochasticity.** Demographic, environmental, life stage-specific, spatially-distributed, etc...

Model Outputs

- **Census Data.** Chronological records of user-defined population metrics.
- **Tabular Reports.** CSV files detailing observed vital rates, movements, interactions, etc.
- **Map-Based Reports.** Map files illustrating population performance and interactions.
- **Videos.** Movies showing movement, resource acquisition, occupancy by trait class, etc.

Life History Events

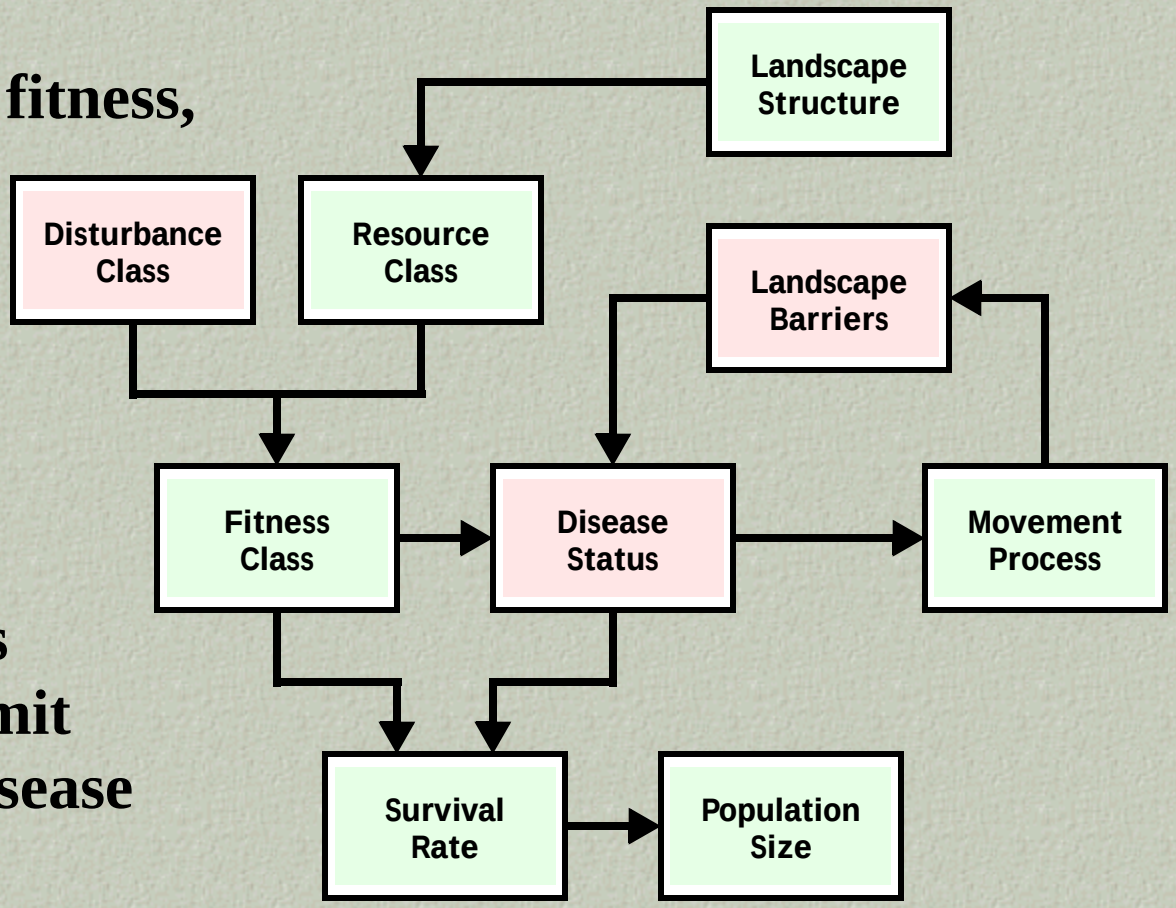
- Survival
- Reproduction
- Movement
- HexMap Generation
- Species Interaction
- Species Introduction
- Mutation
- And so on...

Trait Types

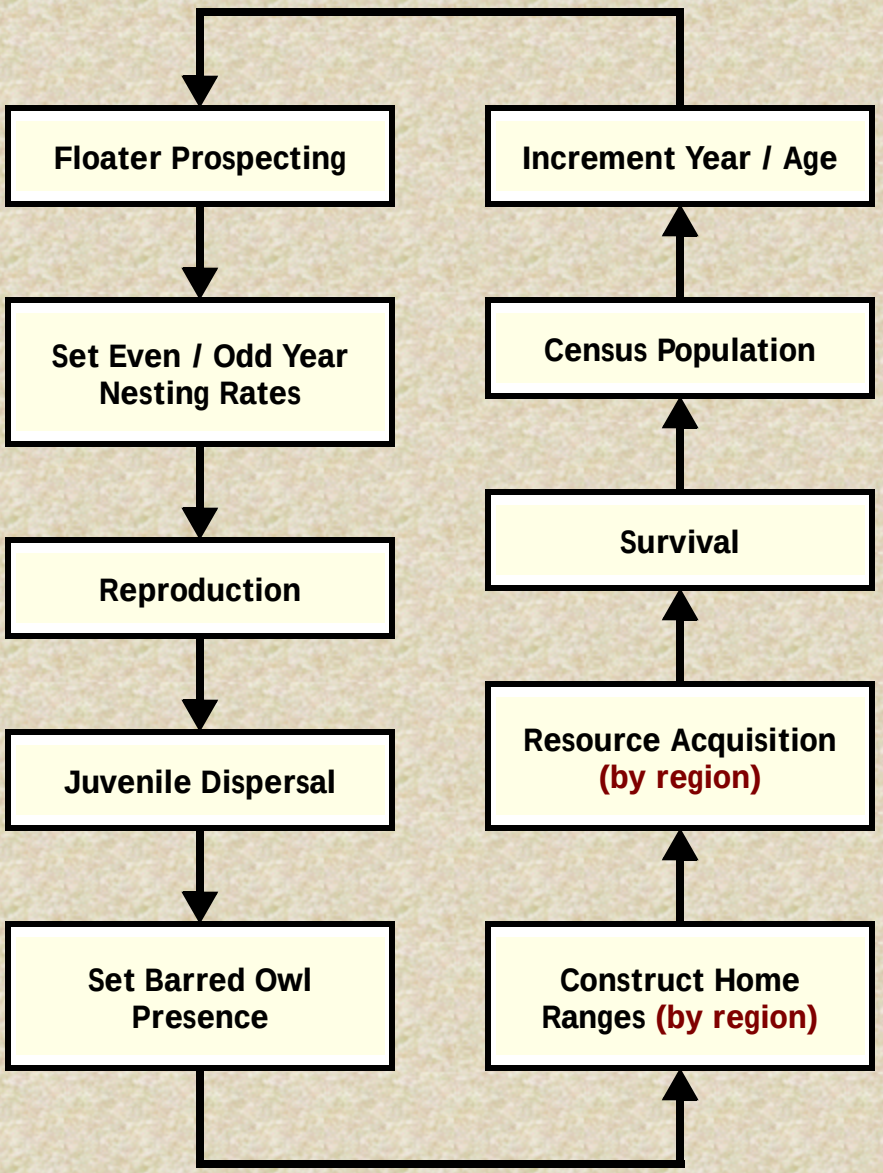
- Probabilistic Traits
- Accumulated Traits
- Heritable Traits

A Hypothetical HexSim Scenario of Moderate-Complexity

- Disturbance affects fitness, which in turn impacts disease status, survival, and reproduction
- Movement barriers affect survival rates because they can limit the spread of the disease

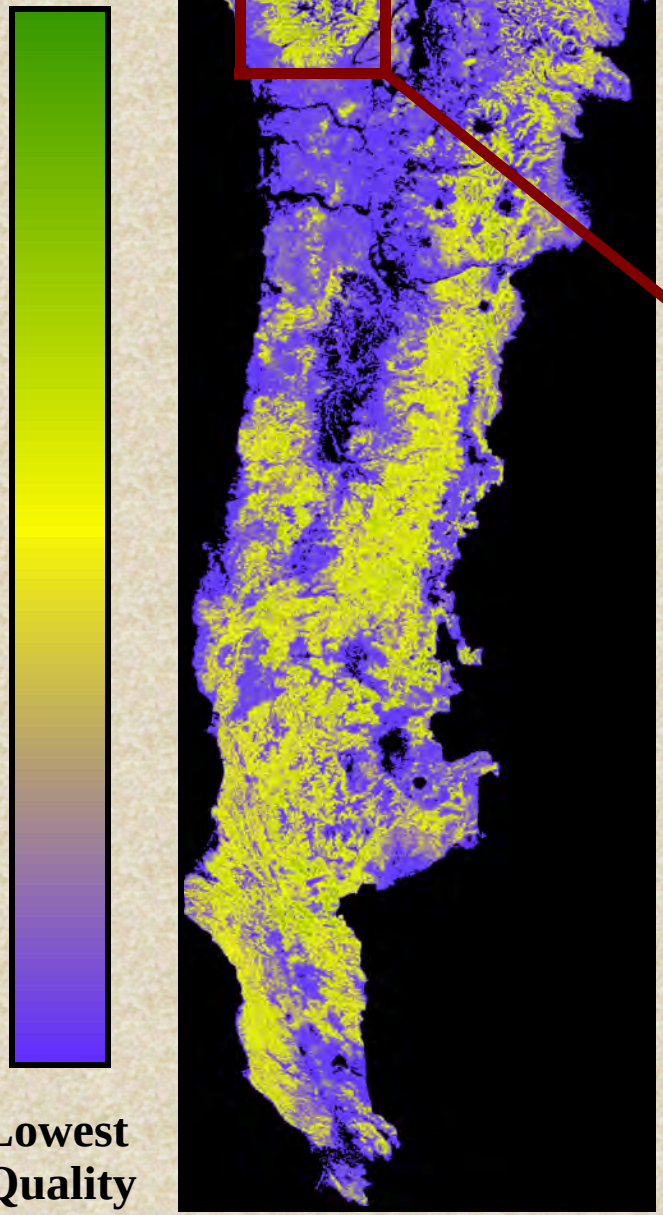


Simulated Spotted Owl Life Cycle

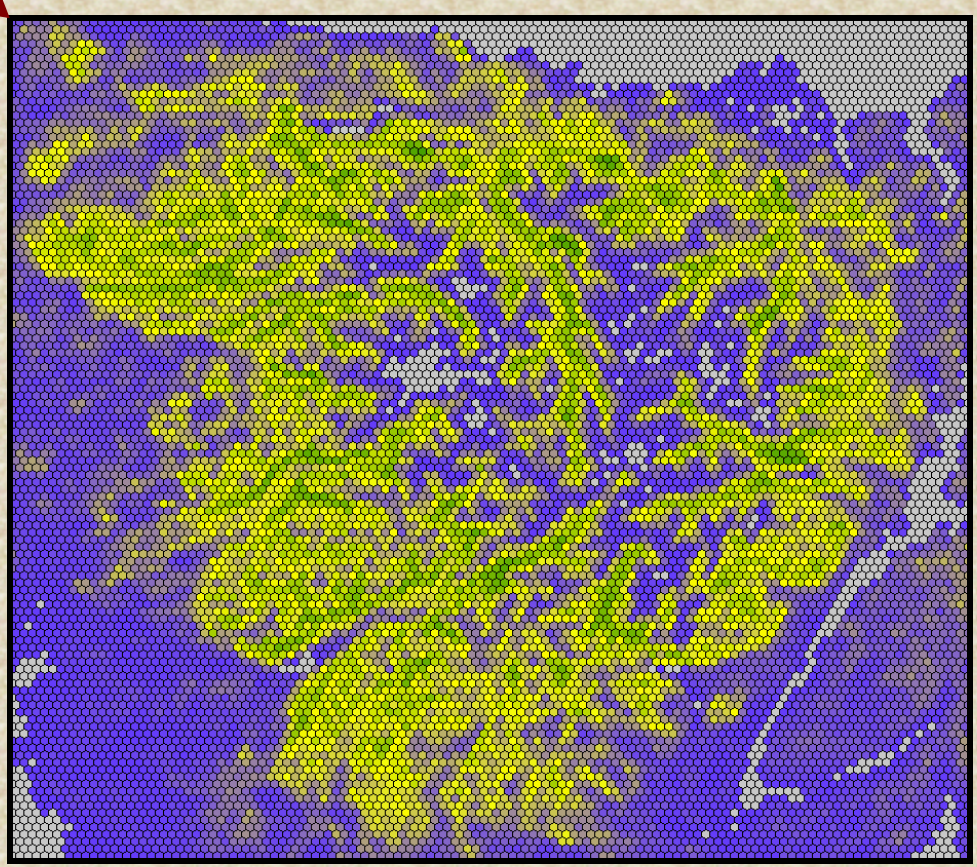


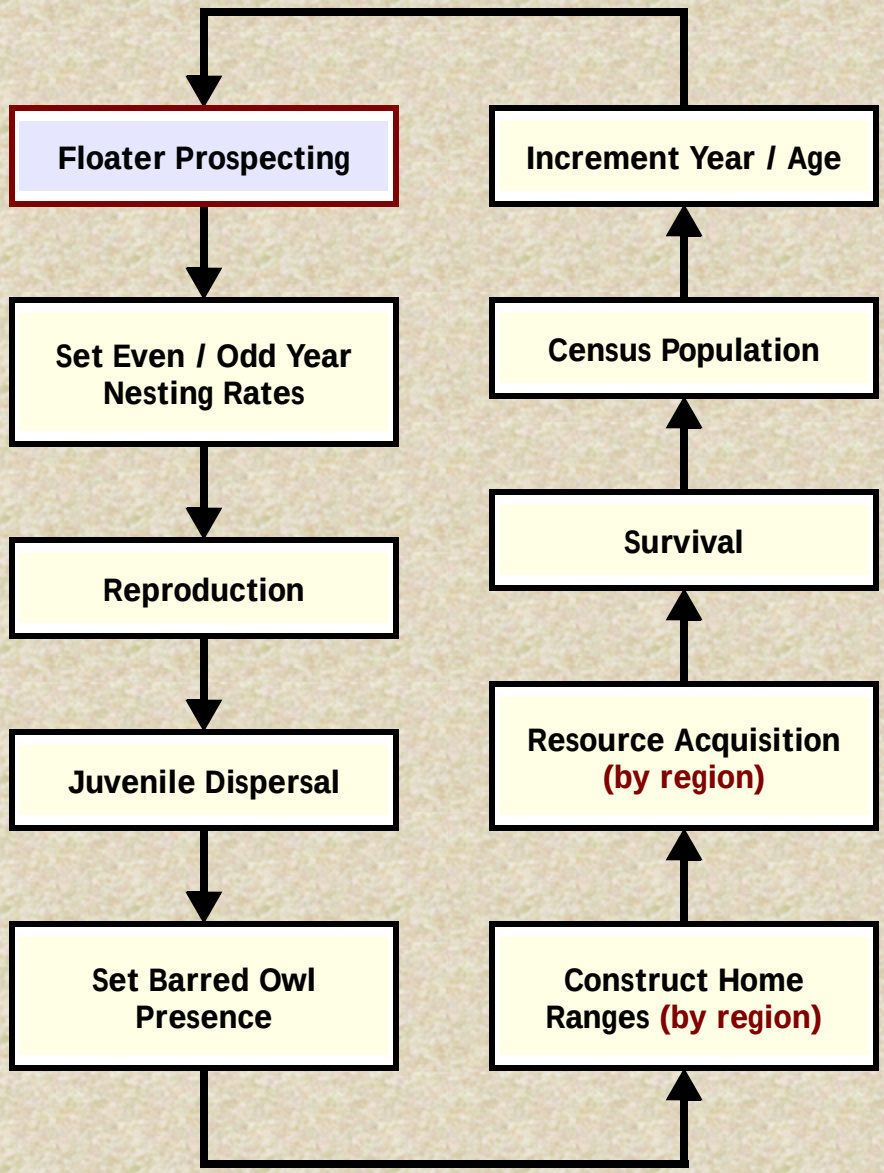
MaxEnt Current Conditions Resource Map

Highest Quality



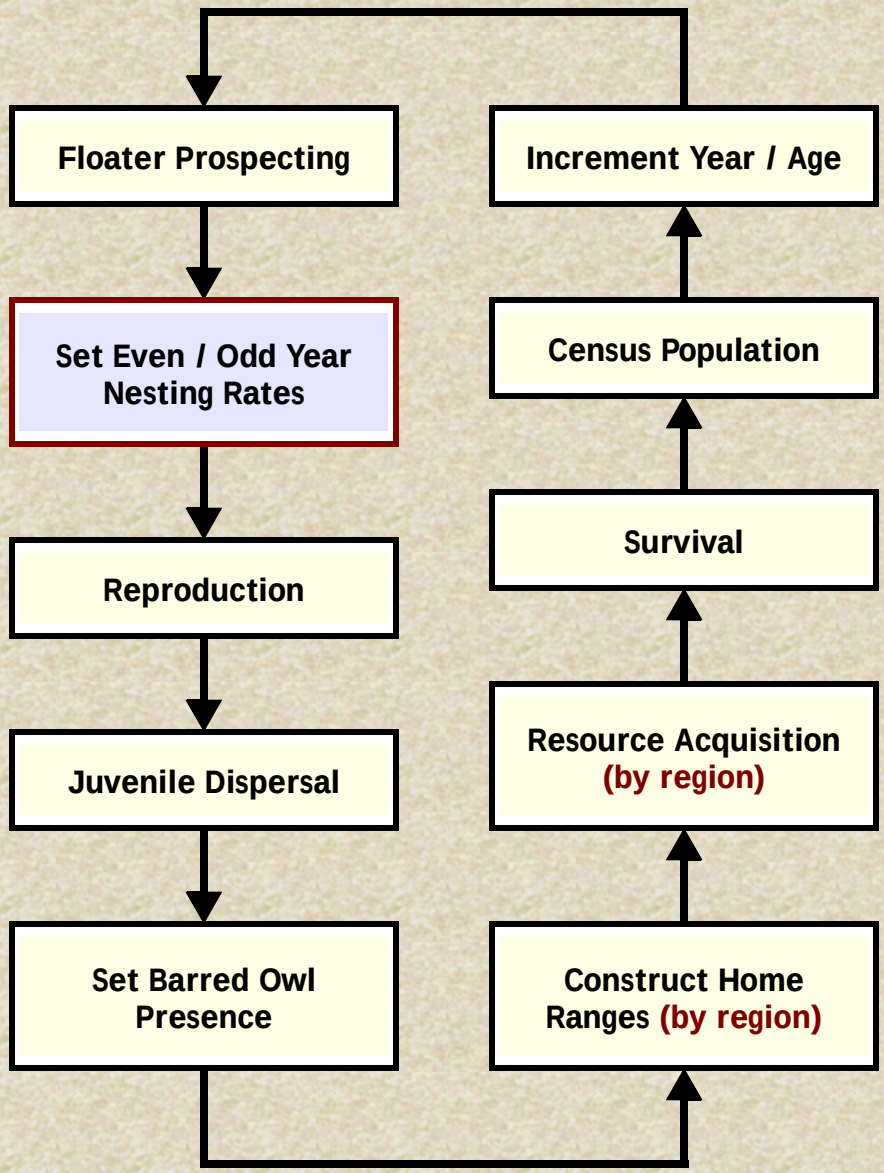
Lowest Quality





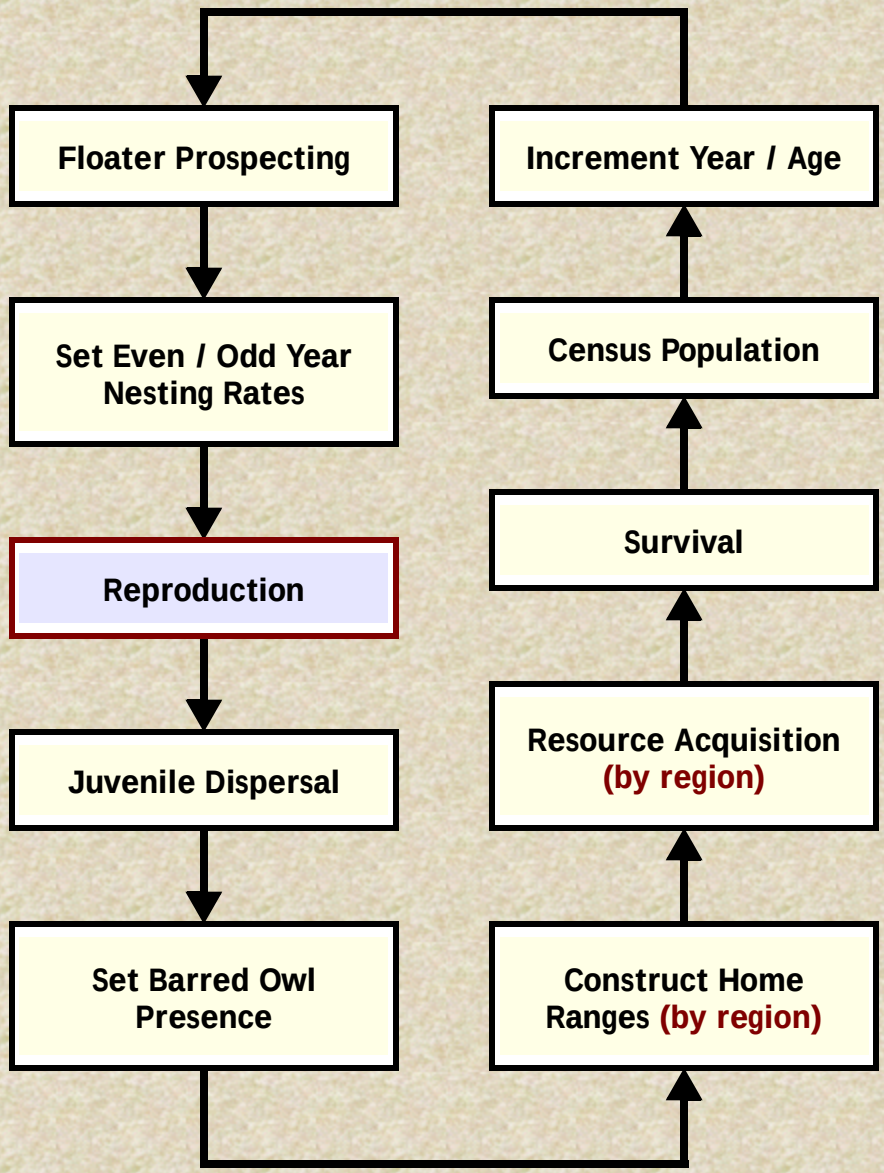
Floater Prospecting

- Applies to all non-territorial birds
- Search area is 500 hexagons (43,300 ha)



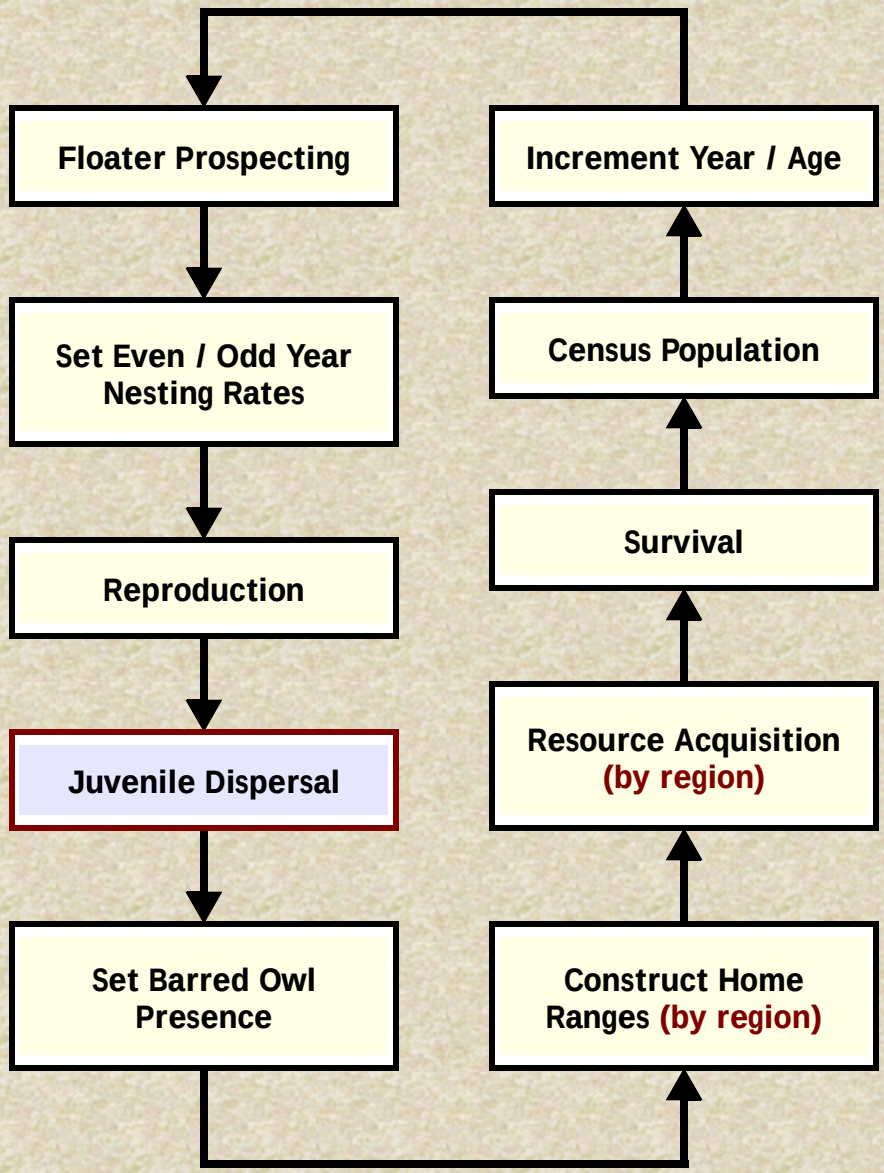
Nesting Frequencies

- In even years, P(nesting) = 70%
- In odd years, P(nesting) = 30%
- On average, P(nesting) = 50%



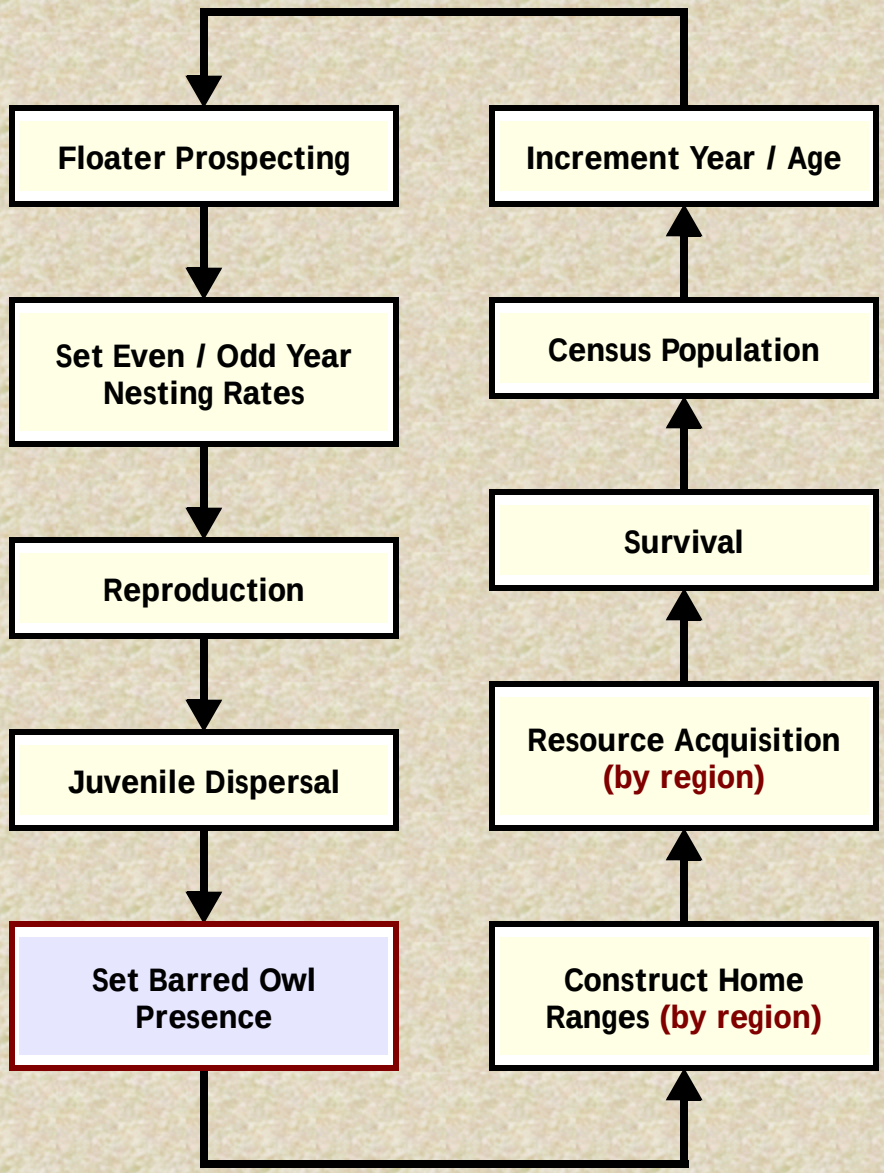
Reproduction

- Fecundities taken from Forsman et. al. (in press)
- *Assumptions:*
  50/50 Sex ratio
  Clutch size = {0, 1, 2}
  P(1) = P(2)
- Measured fecundities are females / female
- HexSim fecundities are females / nesting female



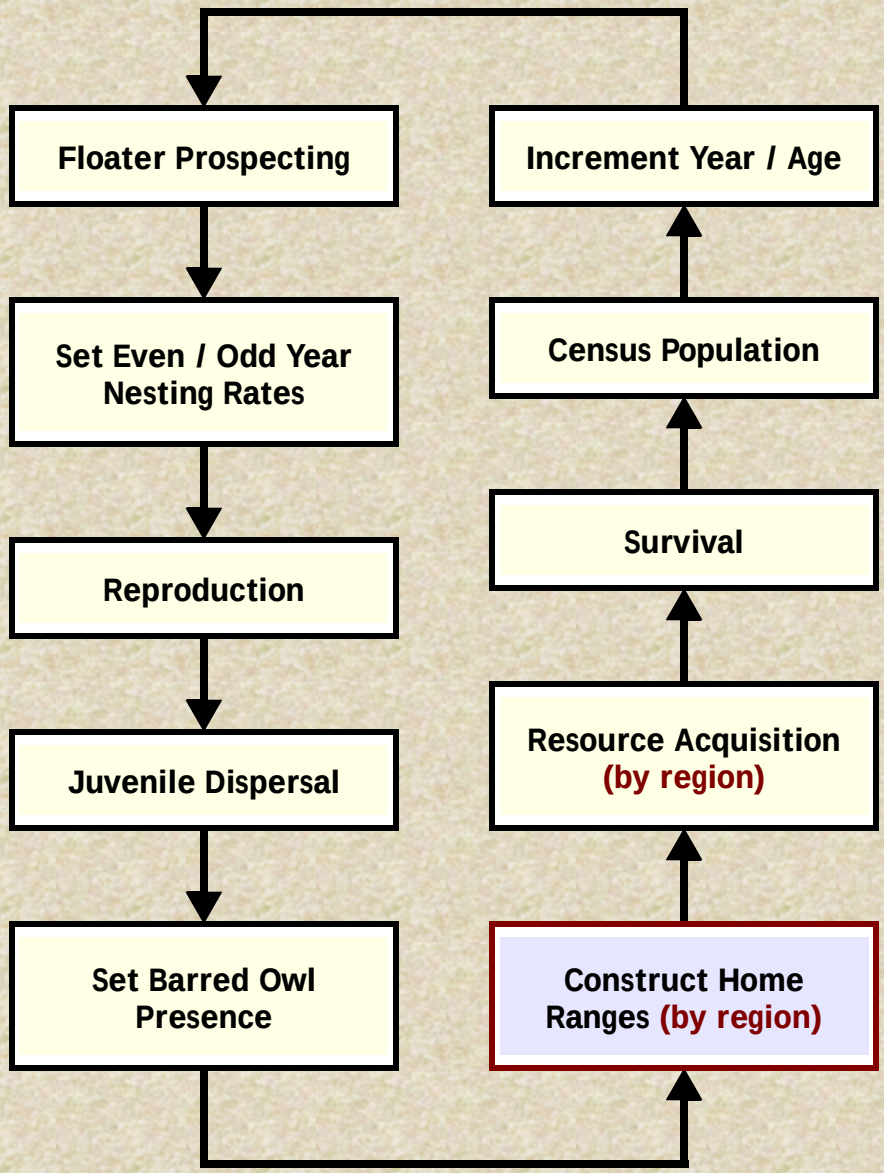
Juvenile Dispersal

- Dispersal only, no prospecting
- Move max of 250 hexagons (250 km)
- Stop if territory-quality resources are encountered
- Tendency to avoid very poor areas



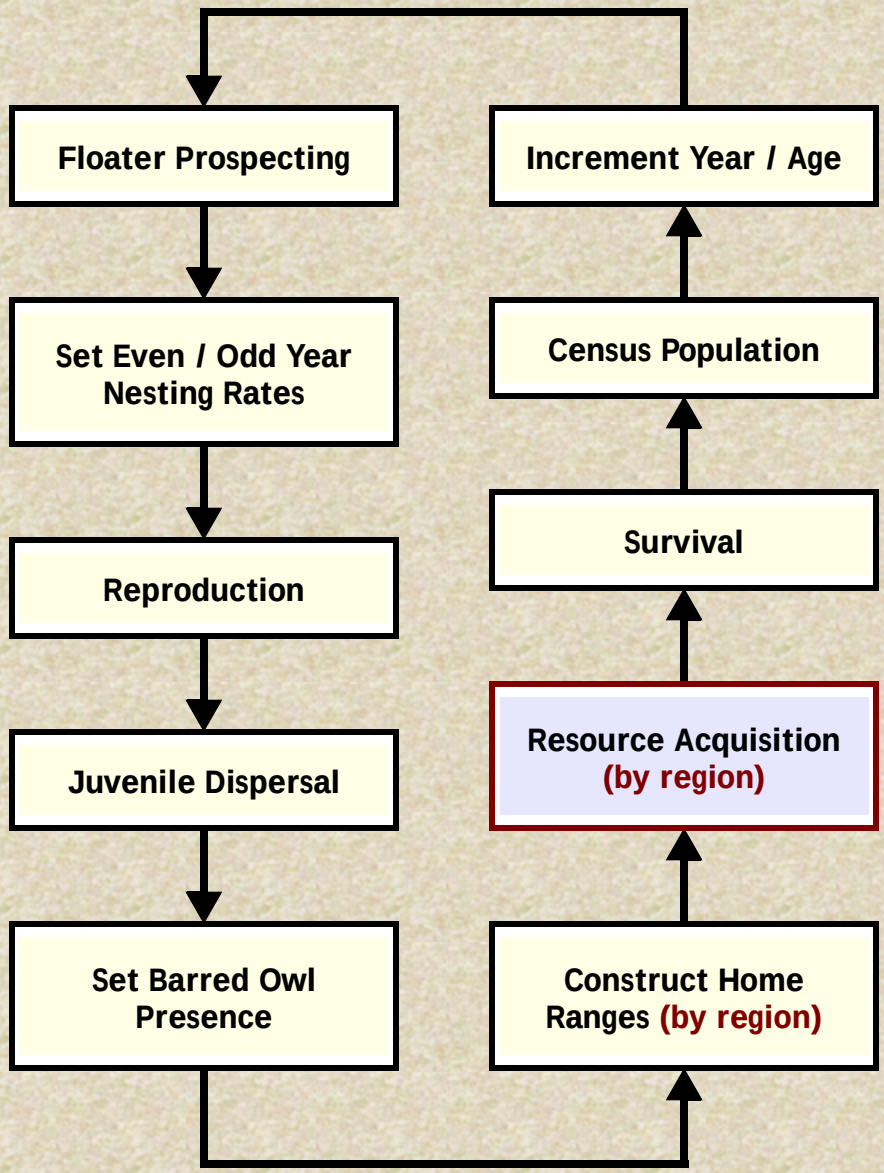
Barred Owl Impacts

- Barred owls affect NSO survival rates
- Stratified by region, otherwise non-spatial
- Barred owl impact is either on, or off
- Determination is made once per NSO



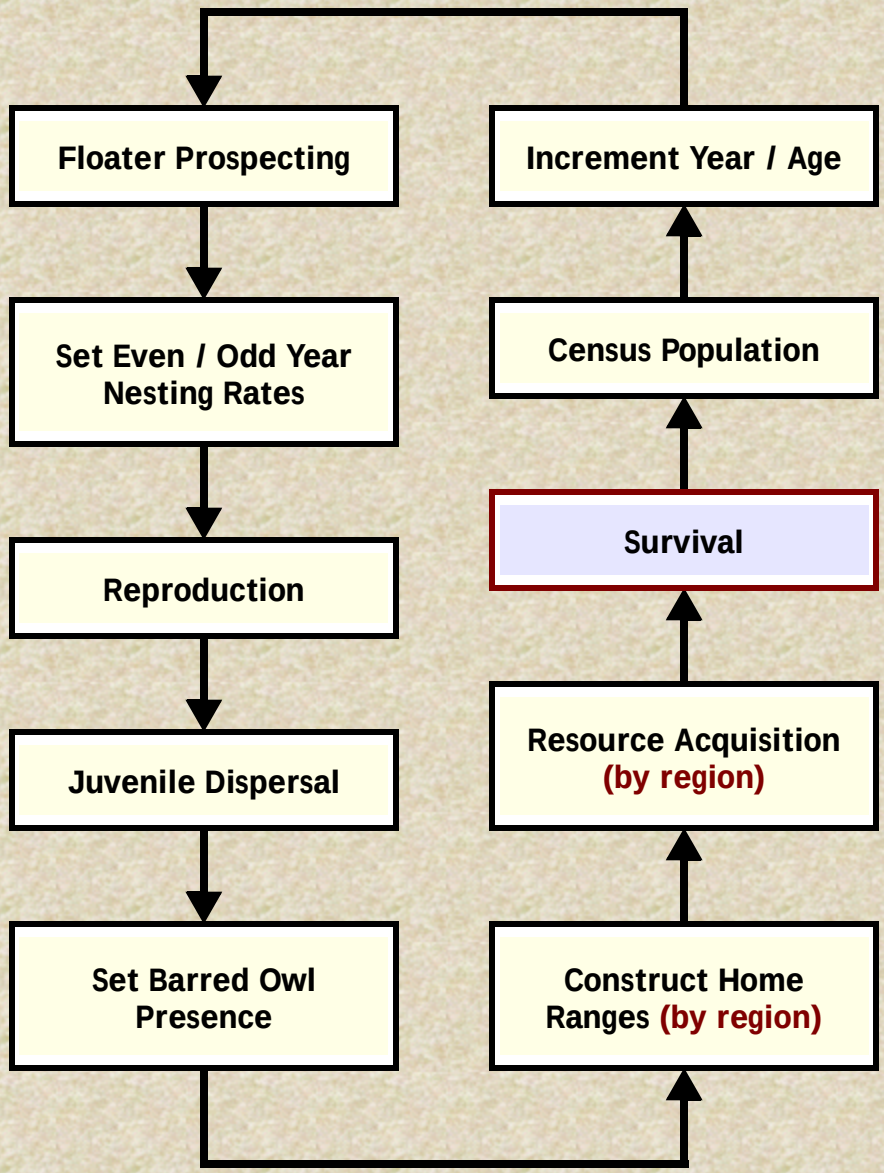
Home Range Construction

- Home ranges are allowed to overlap
- Home range size is stratified by region
- Owls share resources in overlapping ranges
- Search strategy is set to sub-optimal



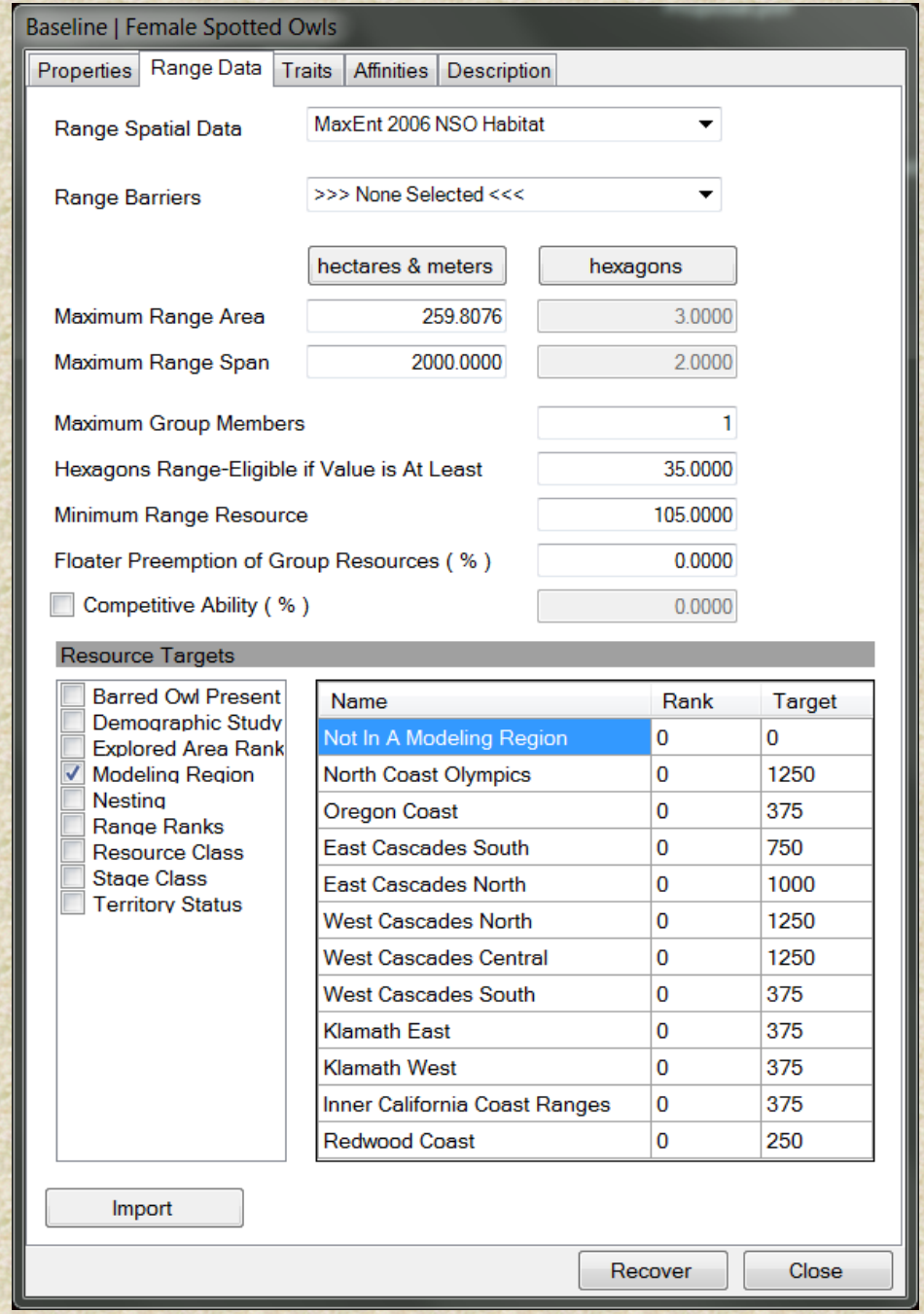
Resource Acquisition

- Resources acquired from home ranges
- Individuals have equal competitive ability
- Owls assigned percent of a resource target
- Resource targets are stratified by region



Survival

- Rates taken from Forsman et. al. (in press)
- Stratified by stage class, resources, barred owls
- Resource classes were low, moderate, high
- Barred owl impacts by Anthony & Dugger



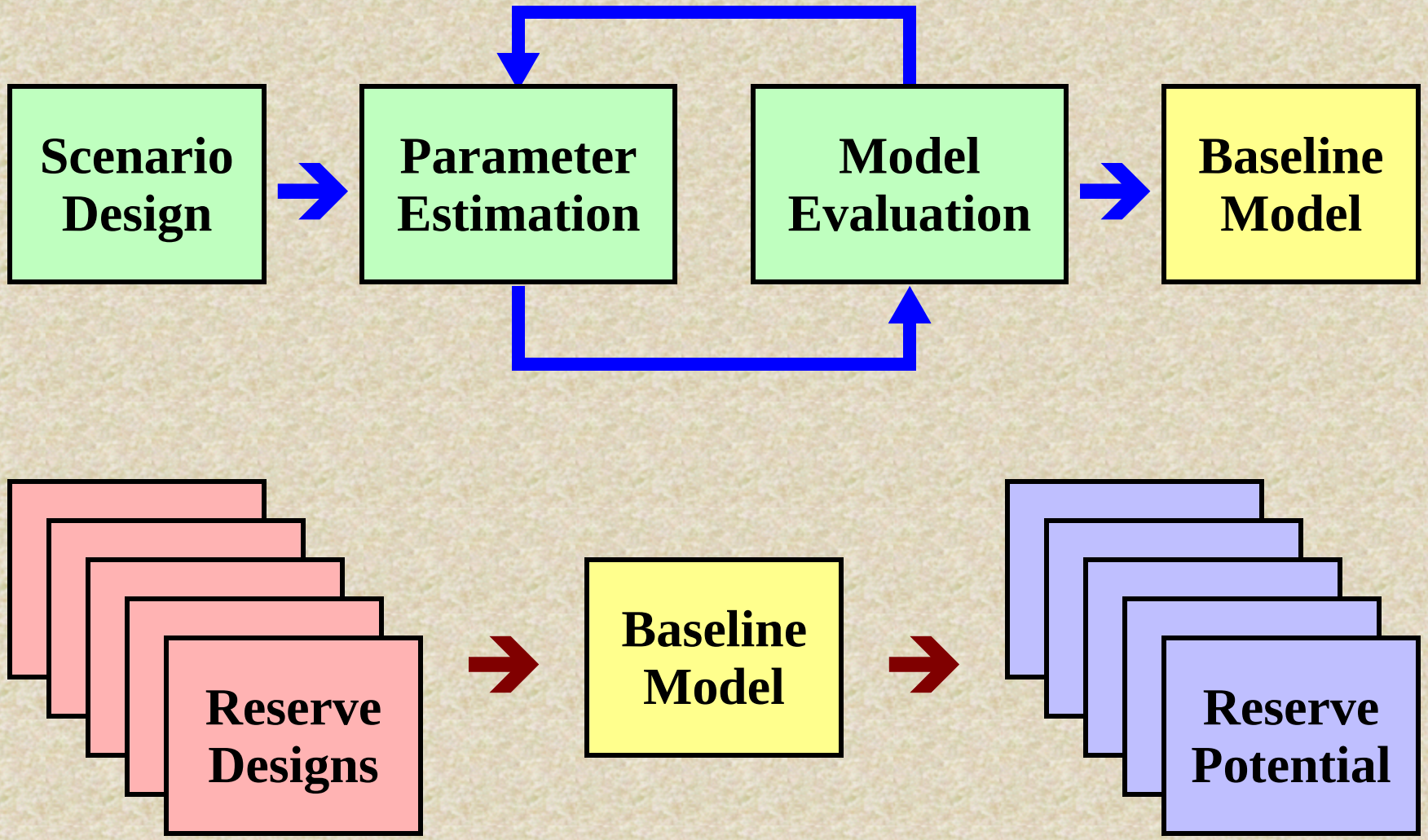
Territory and Home Range Data

- **Territory size small and constant (2-3 hexagons)**
- **Resources acquired from home ranges**
- **Resource targets stratified by region**
- **Resource targets mimic resource density**
- **Targets affect survival via acquisition classes**

Is our HexSim Model a Reasonable Approximation of Reality?

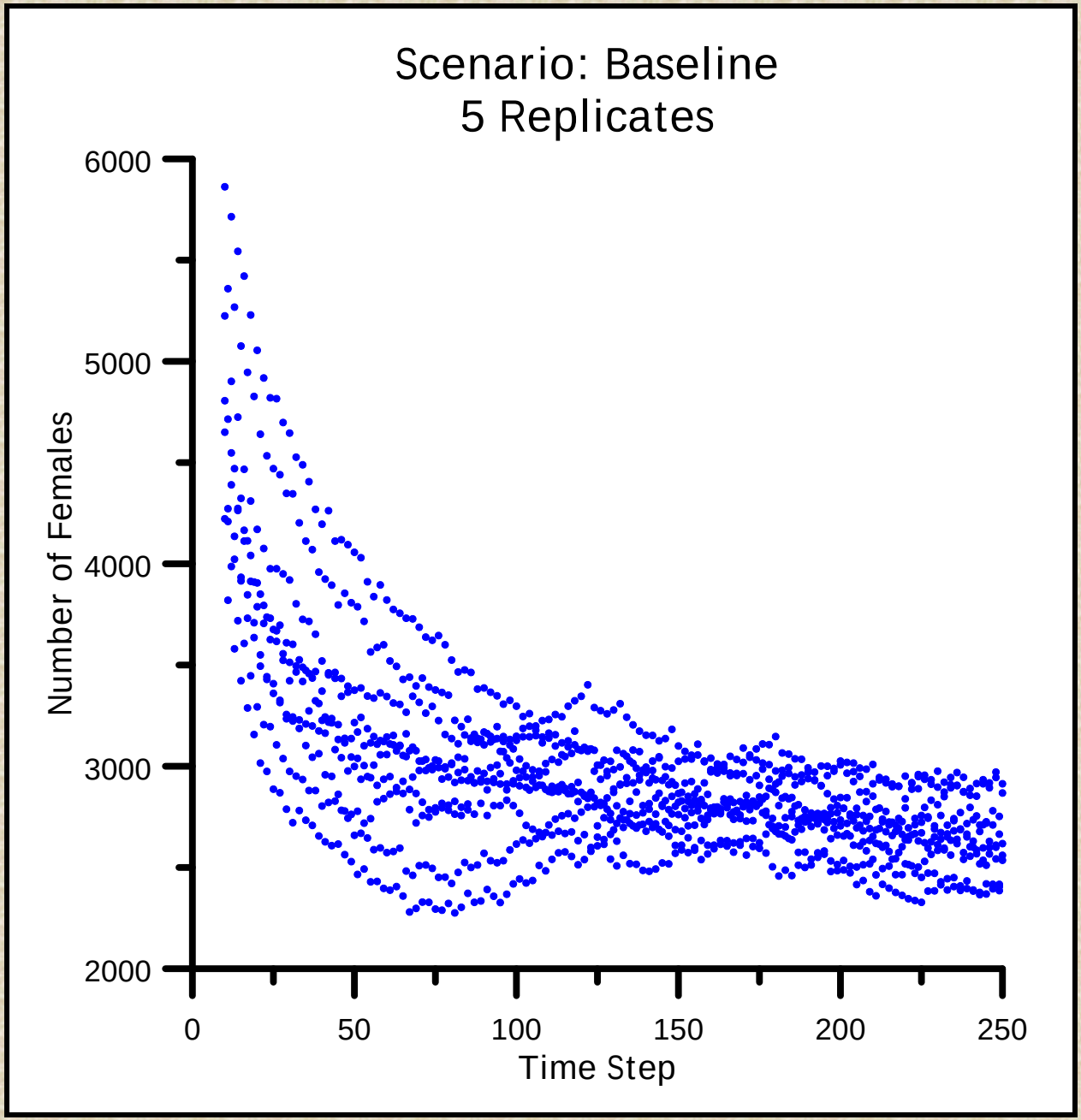
- ➔ **The scenario is actually quite simple.**
- ➔ **The life history events are parameterized using the latest data, and are conservative.**
- ➔ **When uncertain, we left features out.**
- ➔ **Our analysis plays to model strengths (for any model), such as relative change.**
- ➔ **Our results are easily replicated by others.**

Using HexSim in the Analysis



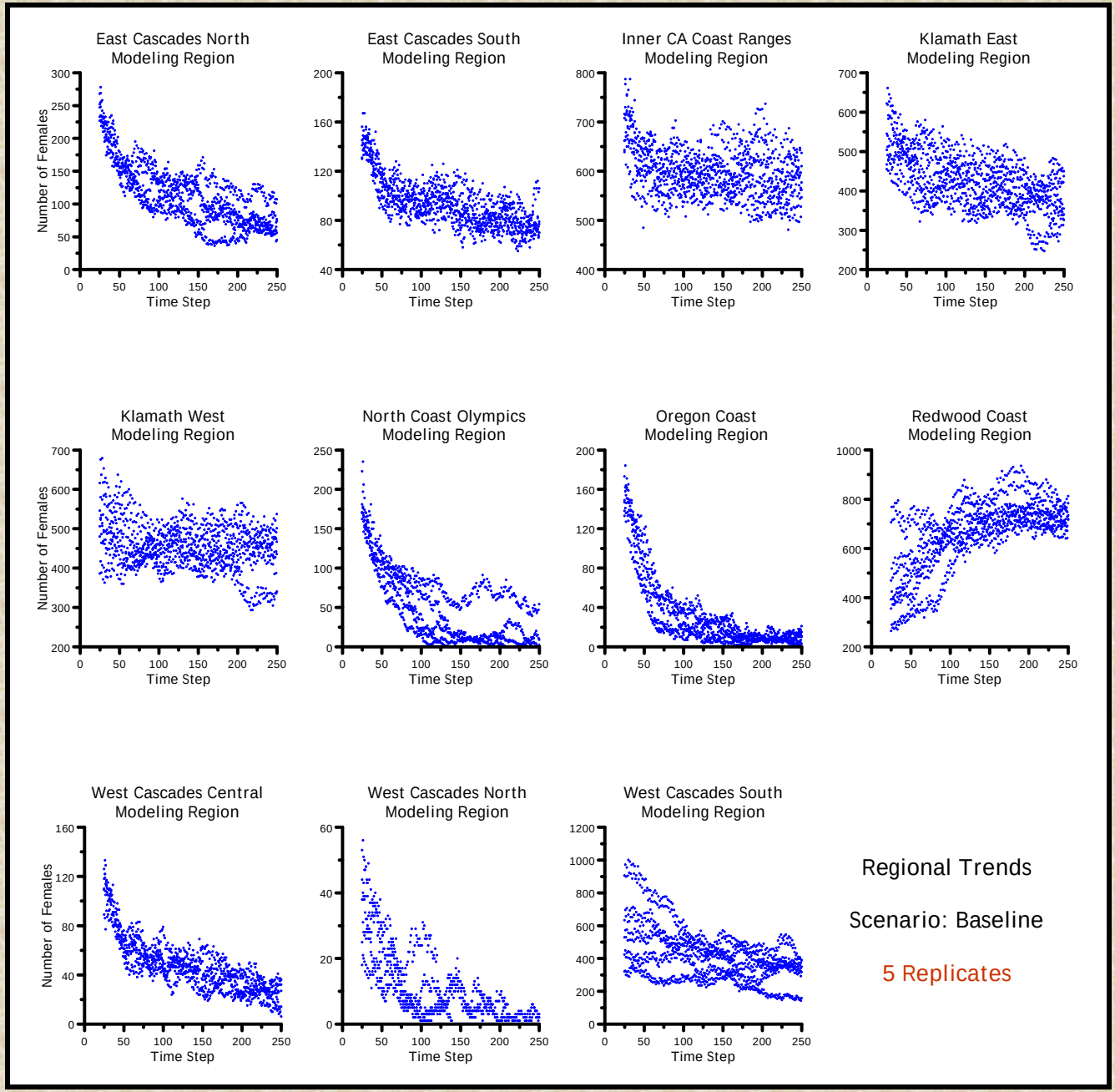
Results

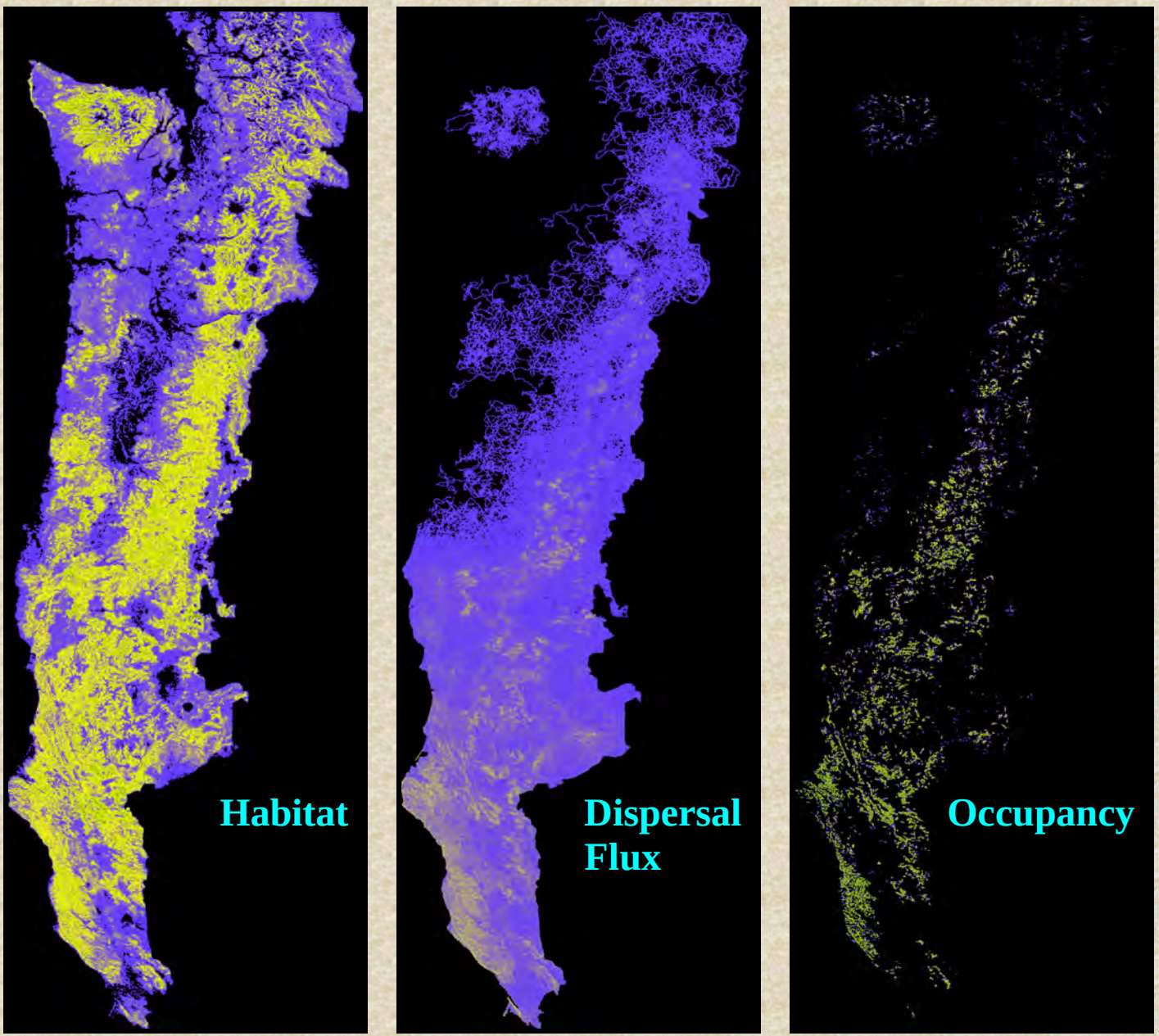
Total Population Size



Results

Population Size by Region




Habitat
Dispersal Flux
Occupancy
Highest Value
Lowest Value

Snapshot of the Dispersal Process